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Clinical Alarms Management in the Intermediate Cardiology and Cardiovascular Intensive Care Units at the University of Iowa Hospital and Clinics

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CLINICAL ALARMS MANAGEMENT IN THE INTERMEDIATE CARDIOLOGY AND
CARDIOVASCULAR INTENSIVE CARE UNITS AT THE UNIVERSITY OF IOWA HOSPITAL AND
CLINICS

by

Aubree Larson

A thesis submitted in partial fulfillment of the requirements
for graduation with Honors in the Industrial Engineering

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Spring 2018

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Cardiology and the Cardiovascular Intensive Care
Units at the University of Iowa Hospital and Clinics

By Aubree Larson, University of Iowa

2018

ABSTRACT

The Intermediate Cardiology Unit (4RC) and the Cardiovascular Intensive Care Unit (CVICU) at the University of Iowa Hospital (UIHC) experience a significant amount of clinical alarms that they have to manage. The clinical alarms monitors have thirty-four different vital signs for patients in the two units, and an alarm will sound when a vital sign or rhythm starts to signal abnormalities. Some of the abnormalities are triggered by a valid clinical condition of the patient, also called an actionable alarm. Alarms that do not fall into the actionable alarm category, called non-actionable and false alarms, have led to alarm fatigue among registered nurses (RNs) and respiratory therapists (RTs) in both units. Alarm fatigue prevents staff from responding appropriately to clinical alarms, resulting in major patient safety issues. The goal of the study is to reduce the number of non-actionable and false alarms by improving alarm management. After alarms per hour per bed were collected for each unit at their current state, an educational program was developed and introduced to the staff in 4RC in an attempt to reduce the alarms per hour per bed. CVICU was treated as a control group with no intervention provided while the educational program was introduced to 4RC RNs. CVICU was held as a control group to determine if mean alarms per hour per bed went down independently with time. Results from both units after the educational program intervention show that the educational program was not effective in decreasing alarms per hour per bed. RNs and RTs still face significant barriers in managing their alarms properly in 4RC and CVICU, and further research needs to be conducted to impact the clinical alarm management problem.

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INTRODUCTION

Literature Review

Issues with clinical alarms management started to gain national attention in the early 2000s.

Although many organizations had been investigating the alarm management problem, it was the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) that first reviewed twenty-three reports of injury or death related to mechanical ventilation. Out of these twenty-three events, “19 resulted in death and 4 resulted in coma; 65% were related to alarms”

(Korniewicz, Clark, David, 2008). JCAHO had previously made it a National Patient Safety (NPS) goal to improve the effectiveness of clinical alarms, but this goal was removed and instead incorporated into JCAHO standards. Despite the new standard, the clinical alarm management problem continued to evolve over the next decade. As the clinical alarms management problem continued to escalate, one root cause was identified: alarm fatigue (Graham, Cvach, 2010).

Alarm fatigue refers to the condition in which medical staff are overwhelmed by the sheer number of clinical alarms. Alarm fatigue can affect patient safety if alarms are mismanaged: disabled, silenced, ignored. This has posed such a large problem that the “ECRI Institute has identified alarm fatigue as the No. 1 technology hazard for 4 years in a row” (Sendelbach, Wahl, Anthony, 2015). Nurses and other medical staff have become desensitized by the frequency of alarms, and this desensitization has prevented them from responding to their patients’ alarms adequately.

Several studies have been published outlining intervention methods to combat the clinical alarms management issue. One study laid out a five step, multi-pronged approach to the issue: (1) deletion of duplicative alarms, (2) customization of alarms on the basis of the patient’s need, (3)

daily changes of ECG electrodes, (4) standardized skin preparation, and (5) use of disposable ECG monitoring leads (Sendelbach, et al). Another approach outlined a similar, but slightly different seven step approach: (1) Provide proper skin preparation for ECG electrodes, (2) Change ECG electrodes daily, (3) Customize alarm parameters and levels on ECG monitors, (4) Customize delay and threshold settings on oxygen saturation via pulse oximetry (SpO2) monitors, (5) Provide initial and ongoing education about devices with alarms, (6) Establish interprofessional teams to address issues related to alarms, such as the development of policies and procedures, (7) Monitor only those patients with clinical indications for monitoring (Sendelbach and Jepsen).

In both cases, a multi-step approach led to a significant decrease in the frequency of alarms in each of the units being studied. Education and training over these critical steps in patient care have a significant impact on clinical alarm management problems.

Background

The University of Iowa Hospital is a comprehensive academic medical center with 811 beds, over 13,000 employees, and a level 1 trauma center rating located in Iowa City, Iowa. In 2017, *Forbes* Magazine ranked it among the top employers in the country in 2017 (Kauflin, 2017). In the fiscal year of 2017, they admitted more than 36,000 patients for in-patient hospital care as well as nearly 60,000 emergency department visits.

The Intermediate Cardiology Unit (4RC) and the Cardiovascular Intensive Care Unit (CVICU) are two in-patient units that specialize in caring for patients experiencing severe cardiovascular issues: massive heart attack, respiratory distress, etc. To assist the nurses with patient care, all patients have their vitals monitored by a Philips Cardiac Monitor™. This monitor tracks thirty-

four parameters including heart rate, blood oxygen saturation levels, and ECG rhythm. These parameters are captured using the 5 leads placed on a patient's torso and their pulse oximeter monitor that is wrapped around a finger. There are default settings for various parameters tracked by the Philips monitors. For example, all patients that are admitted to these units have their maximum high heart rate set at 150 bpm and their minimum low heart rate set at 50 bpm. All relevant default parameters are shown in tables 1 and 2 in the appendix. If a patient were to experience a heart rate outside of these two parameters, an alarm will sound next to the patient's bedside and at the monitoring station located in the center of the units. Unfortunately, the patients seen in 4RC and CVICU have cardiology problems, so they are frequently experiencing vital signs outside of the default settings. However, there are certain alarms that sound that do not have clinical relevance: false alarms and non-actionable alarms. False alarms occur when there is no valid patient related event that triggered the alarm. For example, if the skin is not prepared properly before leads are placed, respiratory rate alarms may sound because the leads cannot accurately measure respiratory rate due to improper placement. Non-actionable alarms correctly sound but for an event that has no clinical intervention. An example of a non-actionable alarm is when a patient has chronic atrial fibrillation (A-Fib) from the moment they are admitted, the patient is not getting treated for the condition, and the A-Fib alarm constantly sounds because it has been kept on. These two types of non-relevant alarms cause nuisance alarms throughout the unit, which has made it near impossible for RNs and Physicians to respond to every single one of their patients' alarms.

The Intermediate Cardiology and the Cardiovascular Intensive Care units are experiencing so many alarms that there are constantly sounding. Consequently, the staff in these units are

experiencing alarm fatigue. The research conducted was to identify solutions to reduce the number of alarms per hour by a statistically significant amount.

MATERIALS & METHODS

The approach to solving this problem requires four steps: identifying the current state of the problem, developing an intervention, educating the staff on the process, and analyzing results of intervention. The cardiovascular intensive care unit will serve as the control group, and the intervention would only be implemented with the intermediate cardiology staff. The analysis of the data will determine if the intervention itself led to a decrease in alarms, or if the quantity of alarms decreased independently with passage of time. The description about the breakdown of steps in the process follows:

Current State Quantitative Data Collection

The first step in data collection was to analyze the current state at which 4RC and CVICU were operating. The metrics we decided to use to analyze the current state were alarms per hour (per bed) and the percentage break down of the different types of alarms in the unit. To calculate these metrics, we analyzed alarms for each bed in a unit in a 24-hour window. To collect this “pre-intervention” data, we performed alarm audits through the Philips monitors (figure 1):



Figure 1: Alarm monitoring home screen on Philips monitors.

From these monitors, we extracted data regarding red and yellow alarms that had been signaled for the patients in a 24-hour period. Red alarms are high priority alarms and indicate that a patient is experiencing conditions outside of the default settings. A yellow alarm indicates that a patient has reached an alarm limit violation (e.g. > 10 premature ventricular contractions in one minute). The other alarm type (blue alarms) sounds due to equipment malfunctions such as a lead coming off or because of low battery in the monitor. These blue alarms cannot be turned off or have their parameters changed, and therefore will not be included in the study. When the red and yellow alarms were collected in the alarm audit, the output data appeared in this form (figure 2):

	A	B	C	D	E
1	Date	Bed Label	Action	Device Name	Clinical User
2	4/19/2018 8:34	4RC681	**SpO2 83 <85 Generated at 08:34:09.	PIIC IX: 4RCSVAH02	
3	4/19/2018 8:34	4RC572	* Pause Ended.	PIIC IX: 4RCSVAH02	
4	4/19/2018 8:33	4RC922	* Irregular HR Ended.	PIIC IX: 4RCSVAH01	
5	4/19/2018 8:33	4RC681	**SpO2 84 <85 Ended.	PIIC IX: 4RCSVAH02	
6	4/19/2018 8:33	4RC681	**SpO2 84 <85 Generated at 08:33:09.	PIIC IX: 4RCSVAH02	
7	4/19/2018 8:33	4RC681	**SpO2 81 <85 Ended.	PIIC IX: 4RCSVAH02	
8	4/19/2018 8:32	4RC681	**SpO2 81 <85 Generated at 08:32:36.	PIIC IX: 4RCSVAH02	
9	4/19/2018 8:32	4RC921	* Non-Sustain VT Generated at 08:32:18.	PIIC IX: 4RCSVAH01	
10	4/19/2018 8:32	4RC91	**NBPs 83 <90 Ended.	PIIC IX: 4RCSVAH01	
11	4/19/2018 8:32	4RC91	**NBPs 83 <90 Generated at 08:32:15.	PIIC IX: 4RCSVAH01	
12	4/19/2018 8:31	4RC041	*** VTach Ended.	PIIC IX: 4RCSVAH02	
13	4/19/2018 8:31	4RC041	***xTachy 211>150 Ended.	PIIC IX: 4RCSVAH02	
14	4/19/2018 8:31	4RC041	***xTachy 211>150 Generated at 08:31:35. (†	PIIC IX: 4RCSVAH02	
15	4/19/2018 8:31	4RC041	* Non-Sustain VT Ended.	PIIC IX: 4RCSVAH02	
16	4/19/2018 8:31	4RC041	*** VTach Generated at 08:31:25.	PIIC IX: 4RCSVAH02	
17	4/19/2018 8:31	4RC041	* Non-Sustain VT Generated at 08:31:24.	PIIC IX: 4RCSVAH02	
18	4/19/2018 8:31	4RC572	* Pause Generated at 08:31:16 (HR = 104)	PIIC IX: 4RCSVAH02	

Figure 2: Raw data collected from alarm audit.

This data provided us information on the exact amount of time alarms were being reported for each bed, the duration of each alarm, and the type of the alarm. First, the data was cleaned so that only the instance the alarm was being generated was evaluated. Also, two alarms were turned on during March (halfway through the analysis) so they will not be included in the study. The two yellow alarm defaults were changed at the beginning of March in the Intermediate Cardiology unit: QT alarms and ST alarms. A QT alarm measures the interval from the start of a Q wave to the end of a T wave in the heart's electrical cycle (figure 3). The ST alarm detects abnormalities

in the ST segment of the heart's electrical cycle. The ST segment refers to the portion of the heart's cycle between the end of the S wave and the beginning of the T wave (figure 3):

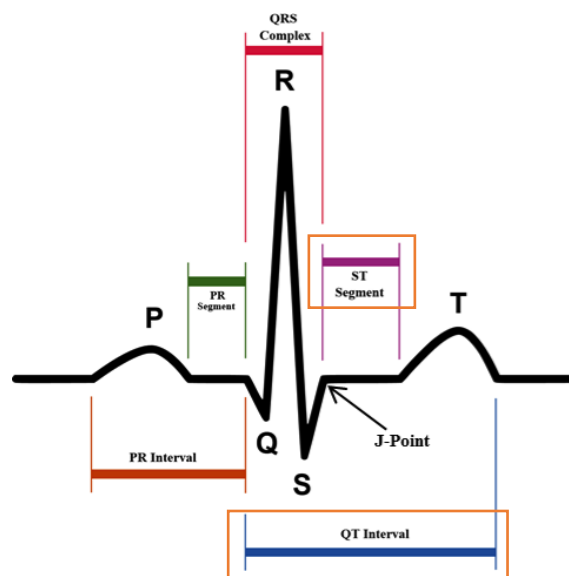


Figure 3: Diagram of the heart's electrical cycle, highlighting the QT interval and the ST segment.

After the unnecessary data had been removed from the initial audit, the average alarms per hour per bed could be calculated for both units (discussed in the results section).

In addition to the mean alarms per hour per bed, we determined which type of alarms was sounding most frequently. This breakdown was calculated after the same data (regarding ended alarms, QT alarms, and ST alarms) had been removed from the initial audit. Knowing the type of the most frequent alarms helped identify the root causes of the false alarm problem. It also helped prioritize the alarms that should be addressed in the educational program to develop as the intervention. The breakdown is shown in figure 4:

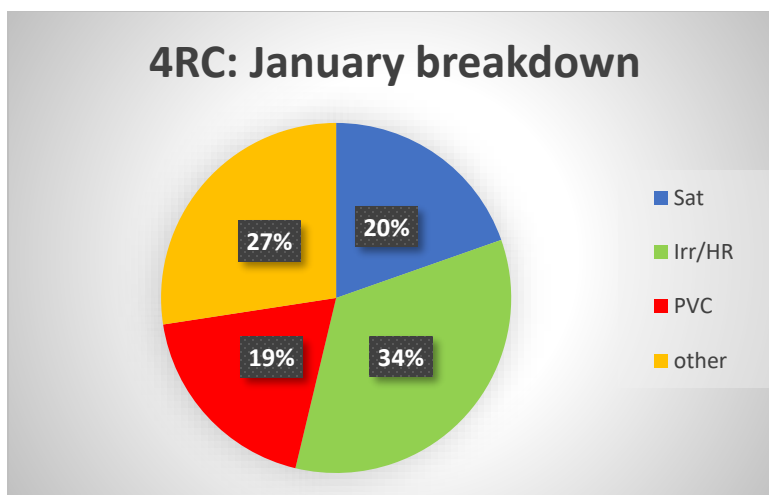


Figure 4: Alarm breakdown for the Intermediate Cardiology unit.

The three alarms that constituted the majority of the unit's total alarms were irregular heart rate/ heart rate, blood oxygen saturation, and premature ventricular contraction (PVC) alarms. After identifying these as the three main contributors to the units' alarm problems, we analyzed how these alarms were measured.

The irregular heart rate/ heart rate and the PVC alarms are primarily measured by five leads that are placed on a patient's torso. These leads are stuck to the patient's skin using adhesive and are required to be changed every 24 hours. The leads measure various vital signs by a frequency that ranges across all five leads. If a lead is placed in the wrong spot, certain organs can block the signal and trigger false alarms. Additionally, if the adhesive starts to diminish and a lead does not properly stick to the patient, a false alarm may be triggered.

Blood oxygen saturation levels are collected from a monitor wrapped around the patient's finger. A small sensor rests on the finger nail, and if the sensor moves around it will improperly read and cause a false alarm. This can happen when a patient is trying to eat while in bed, while they are moving around in bed, or if their movement slides the monitor into an incorrect position.

Current State Qualitative Data Collection

Once the quantitative data had been collected, qualitative data was obtained from the front-line workers in both units to determine their perceptions of the alarm problem. A survey was sent to approximately 80 nurses with questions aimed at understanding strategies to better assist the nurses with the daunting task of managing their alarms. This survey aimed at identifying the barriers the front-line workers experience when attempting to manage their alarms.

With a qualitative and quantitative understanding of the alarm management problem, an educational program was built to support RNs to manage these alarms better.

Intervention Development

Combining the data collected from the current state analysis, three main reasons were identified as the primary contributor to the clinical alarm management issue:

1. Lack of empowerment of RNs to allow them to change patients' alarms as they see appropriate
2. Incorrect lead placement
3. Lack of knowledge on process for changing alarm parameters

After these three root causes had been identified, an educational program was created based upon the four steps of the implementation strategies for evidence based practice developed by the Department of Nursing at UIHC. The four major steps that the strategy lays out are “create awareness & interest, build knowledge & commitment, promote action & adoption, and pursue integration & sustained use” (Cullen, 2015). The current state data analysis and the questionnaire sent out helped create awareness and interest within the staff involved in the two cardiology inpatient units. The educational program that would be developed would span the second and

third steps listed by the Department of Nursing in order to have the nurses and other staff commit to making a change with clinical alarms management and working towards adopting the new strategies into their everyday work flow. The integration and sustained use will be a continuous process moving forward in order to ensure the changes made initially continue to make an impact in the future. The first portion of this educational program was a power point presented to the 4RC staff by their nurse managers and two nurse champions, informal leaders among the nursing staff in the unit.

The power point first discussed the quantitative data collected and displayed the clinical alarms management problem in numerical terms. Then, the educational portion started with an overview of the policy and protocol for allowing RNs to adjust their patients' alarms. The policy titled "Clinical Alarms Management- Adult, Inpatient" lays out all the steps and necessary actions required when monitoring a patient's vitals. Under the Procedure section, Part C defines that clinical alarm settings can be adjusted per the "Clinical Alarms Management Protocol." This protocol contains the details of how an order can be adjusted by an RN or Respiratory Therapist (RT) in inpatient units. Section IIIB states that "multiparameter alarms can be adjusted by $\pm 10\%$ from default baseline settings" and that RNs and RTs can "adjust arrhythmia alarms... as needed to maintain safe patient monitoring" (University of Iowa Hospital and Clinics: PC-PCI-05.38). This policy and protocol was specifically designed to empower nurses to make safe clinical decisions regarding their patients' alarms.

The second portion of the power point addressed correct lead placement for all patients and other necessary steps to make sure the leads read properly. Factors that can affect a lead's ability to read are improper skin contact such as too much hair between the lead and the patient's skin, too

much moisture on the skin, or many other conditions listed in figure 5. A figure developed by Philips was extracted from a previous educational program from UIHC and is shown in figure 5:

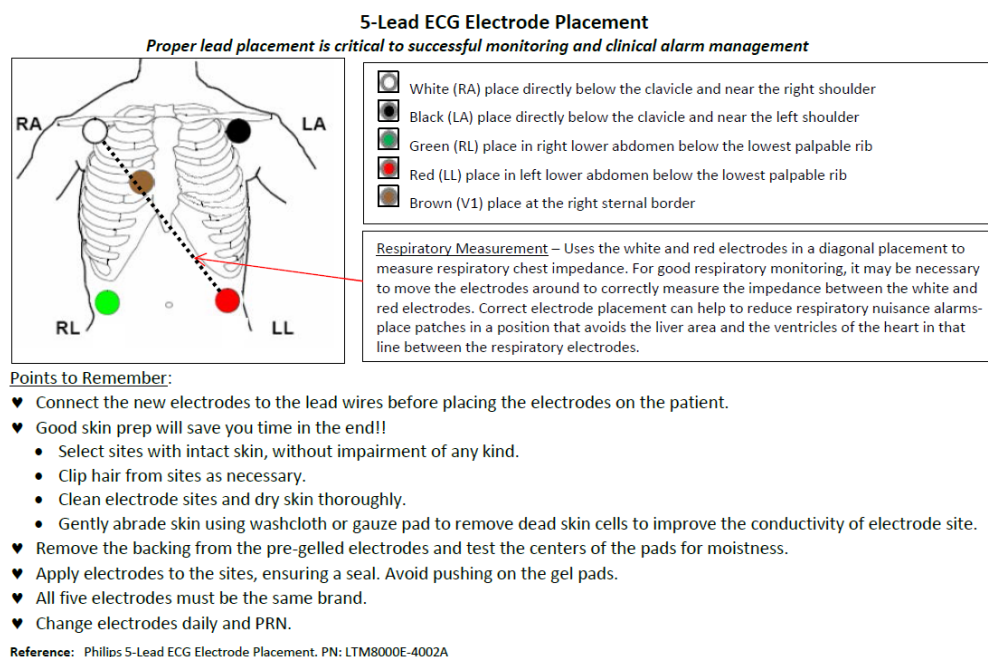


Figure 5: Guidelines used for correct lead placement (Philips 5-Lead ECG Electrode Placement).

The third portion of the presentation walked through the process of changing alarm parameters in two separate sections: adjustments on the Philips Monitor and active orders in the electronic health record system. The most important portion of this educational portion was introducing the decision tree necessary to decide if changing alarm parameters/ settings was appropriate (figure 6):

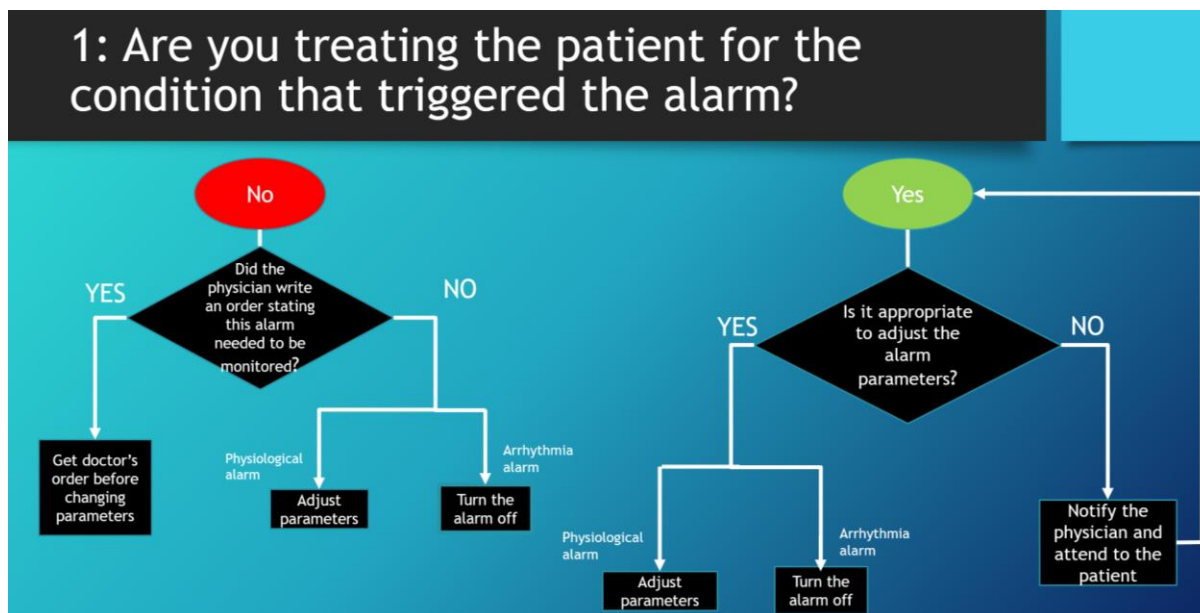


Figure 6: Decision tree regarding changing a patient's alarm parameters/ settings.

This decision tree sought to clarify when an RN could, for example lower the low heart rate alarm from 50 bpm to 45 bpm or shut off the QTC alarm if necessary.

To avoid having an RN change the alarm parameters beyond the or turn off an ECG alarm, the default baseline parameters and the decision tree were printed and displayed next to the Philip Monitors. This allowed for the information to be visible and readily accessible while they were adjusting their patients' alarms in real time.

After the power point had been presented to the majority of the nursing staff at 4RC, hands on education was provided to the RNs throughout their shifts. Nurse Managers, champion nurses, and those involved in the intervention development phase of the research project sat next to the Philips Monitors and helped staff work through the steps to change the necessary alarms. After a few weeks of this educational process, results were collected and analyzed to determine if the intervention strategies were significantly effective.

Post Intervention Quantitative Data Collection

Similar to the current state quantitative data collection, alarm audits were extracted from each unit over a 24-hour period and analyzed. The analysis was done through a two sample t-test of the means for pre versus post intervention alarms per hour per bed. The results from this analysis will further be discussed in the results section.

RESULTS

Current State Quantitative Results

After three months of collecting data (January, February, and March) we could conclude that the Intermediate Cardiology unit was experiencing a mean of 3.73 alarms per hour per bed with a standard deviation of 4.2 alarms per hour per bed. The breakdown of the mean is shown in the descriptive statistics in figure 7:

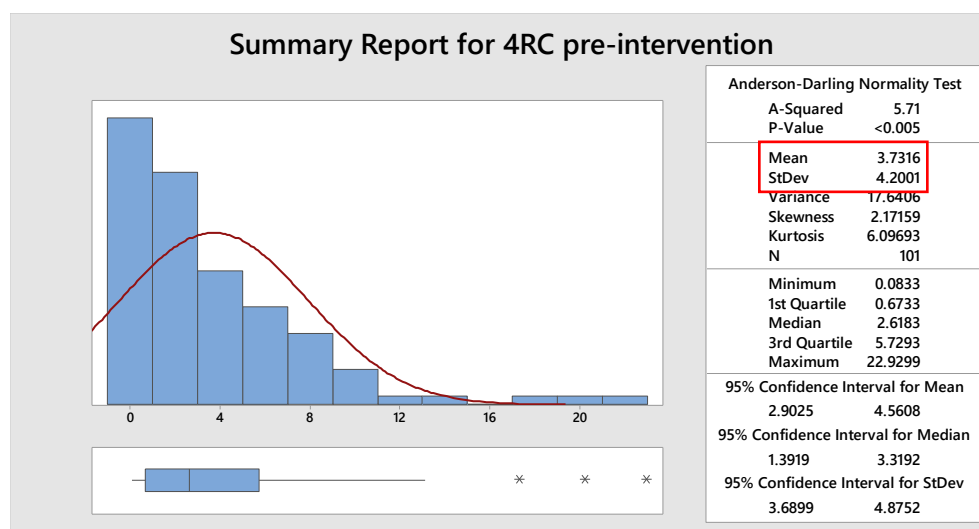


Figure 7: Descriptive statistics for the mean alarms per hour per bed for 4RC.

The Cardiovascular Intensive Care Unit was experiencing a mean of 5.05 alarms per hour per bed with a standard deviation of 3.65 alarms per bed per hour. The breakdown of the mean is shown in the descriptive statistics in figure 8:

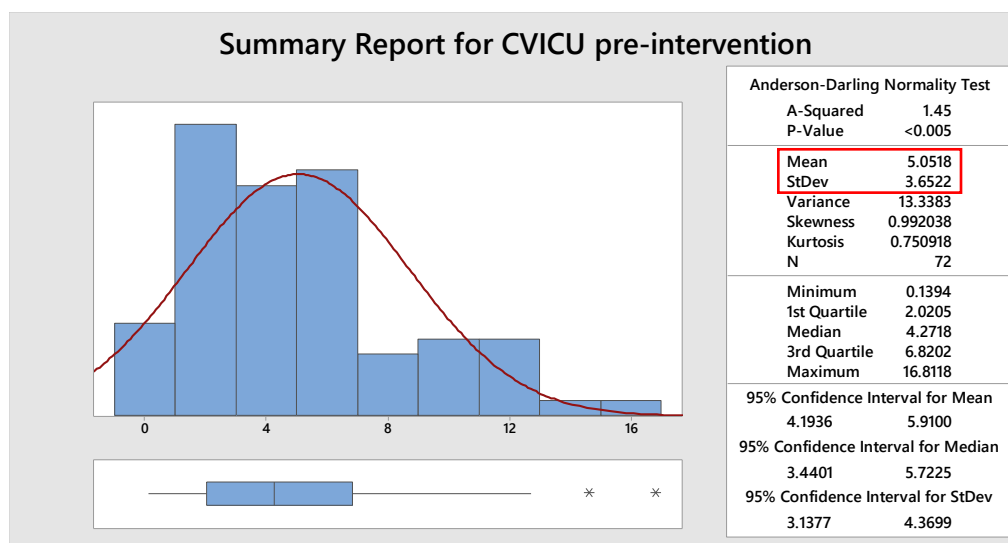


Figure 8: Descriptive statistics for the mean alarms per hour per bed for CVICU.

With a capacity of around 30 beds per unit, the RNs on the units were hearing more than 120 alarms per hour, that is, more than 1 alarm every sixty seconds. An RN attends to 3-4 patients typically, so with the current state they are attending to an alarm nearly once every 5 minutes. The mean from 4RC will be compared with the mean after intervention with intent to see a significant decrease in alarms per hour per bed. The same comparison will be done for pre and post intervention data from CVICU, to study if the mean remains fairly constant.

Current State Qualitative Results

The results from the survey administered to the nurses helped determine the barriers nurses face when managing alarms. The survey results showed that more than half (56.41%) of nurses believed that between 50%-75% of their patients' alarms were either false or non-actionable

alarms (figure 9 in the appendix). The survey also showed that the same nurses stated that they did not change their patients alarms often (figure 10):

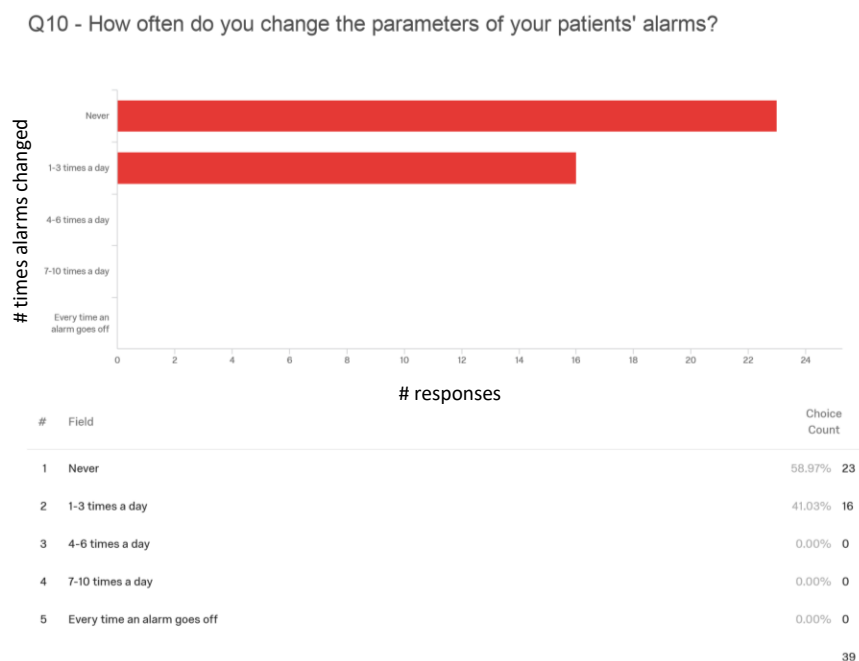


Figure 10: Survey results detailing how often RNs change the parameters of their patients' alarms.

These results were used to build the educational program with the goal of empowering RNs and RTs to change their patients' alarm parameters.

Post Intervention Quantitative Results

Three weeks after the educational intervention had been introduced to the staff and one week after hands on training had begun, post intervention data was collected to determine if the educational program was effective in helping RNs manage their alarms. The same process used in pre-intervention was used to export the audits, and the same alarms were taken out of the study so that the breakdown matched the pre- intervention data collected. The data showed that

4RC was experiencing an average of 3.73 alarms per hour per bed with a standard deviation of 5.52 alarms per hour per bed. The breakdown of the mean is shown in the descriptive statistics in figure 11:

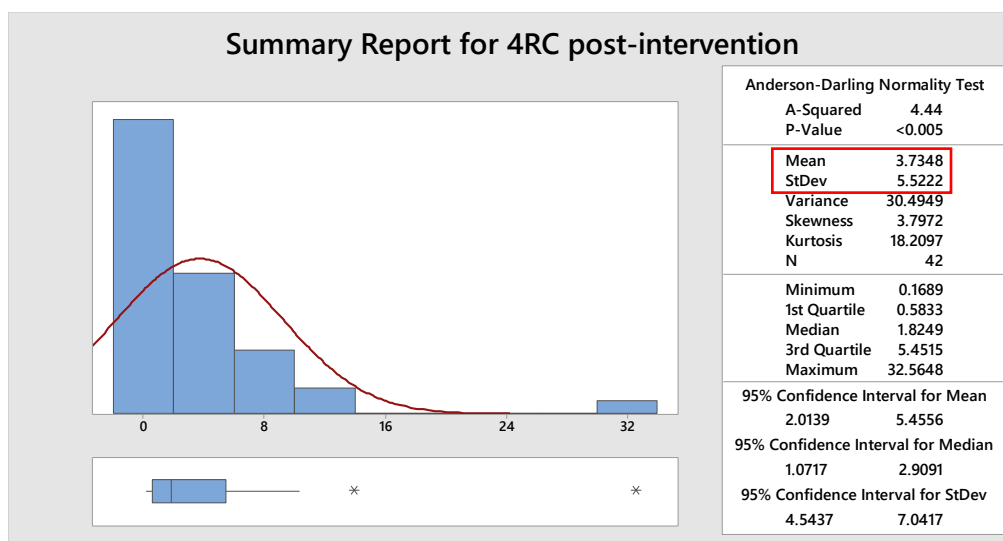


Figure 11: Descriptive statistics for the mean alarms per hour per bed for 4RC.

The CVICU was experiencing a mean of 4.46 alarms per hour per bed with a standard deviation of 3.87 alarms per hour per bed. The breakdown of the mean is shown in the descriptive statistics in figure 12:

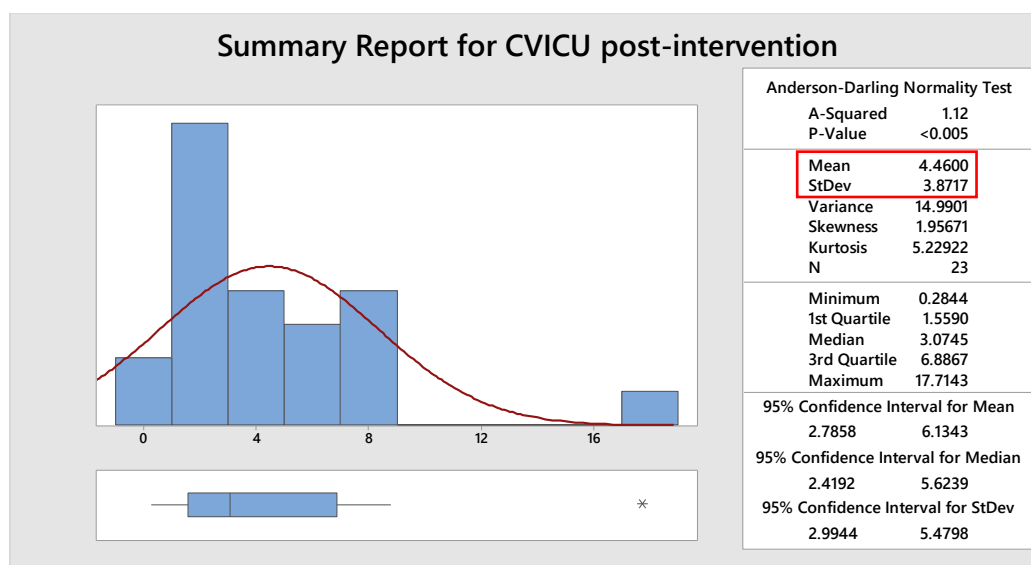


Figure 12: Descriptive statistics for the mean alarms per hour per bed for CVICU.

To determine if a significant change in the mean alarms per hour per bed had occurred between the pre-intervention and the post intervention data in the two units, a two sample t test was conducted using the Minitab software. The first step in this analysis was to determine if the two samples (pre versus post) had equal variances. The equal variance test has a null hypothesis that states the two data sets being tested will have significantly equal variances at the 95% confidence level. For the equal variance test for 4RC, the p-value of the test was 0.90, which was greater than the significance level of 0.05, so the null hypothesis stands that the two variances are significantly equal. The results showed that the variances between the two samples was significantly equivalent (figure 13):

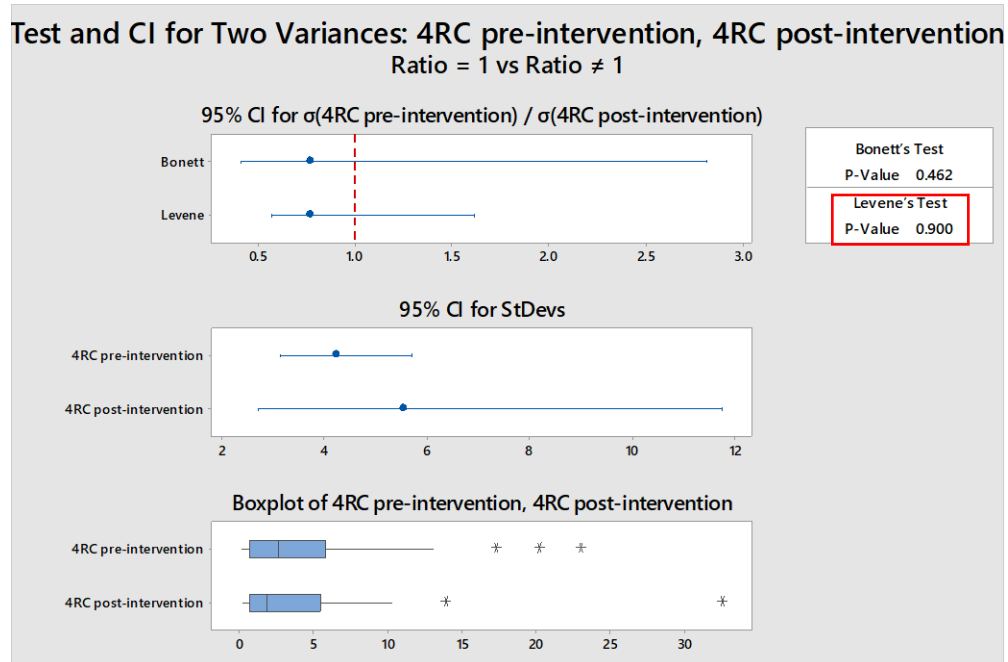


Figure 13: Equal variance test between pre and post intervention data collected in 4RC.

After the equal variance assumption was proved, a two sample t test was run between the pre and post intervention data for 4RC. The two sample t test has a null hypothesis that the two means of the data are significantly equivalent at the 95% confidence level with equal variances (previously tested). The p-value obtained from this test, 0.997, is greater than the significance level of 0.05 so the null hypothesis was not rejected, and it was concluded that the means were not significantly different. The results from the two sample t-test run in Minitab are shown in figure 14:

Two-Sample T-Test and CI: 4RC pre-intervention, 4RC post-intervention

Two-sample T for 4RC pre-intervention vs 4RC post-intervention

	N	Mean	StDev	SE Mean
4RC pre-intervention	101	3.73	4.20	0.42
4RC post-intervention	42	3.73	5.52	0.85

Difference = μ (4RC pre-intervention) - μ (4RC post-intervention)
 Estimate for difference: -0.003
 95% CI for difference: (-1.681, 1.675)
 T-Test of difference = 0 (vs \neq): T-Value = -0.00 P-Value = 0.997 DF = 141
 Both use Pooled StDev = 4.6237

Figure 14: Results from the two sample t-test run between pre and post intervention for 4RC.

After the equal variance and two sample t-test were run using the data from 4RC, the same was done for CVICU; keeping in mind that the data for CVICU will be referred to as pre and post intervention, but the intervention was not tested in CVICU since it is the control group. The pre and post intervention labels are just to refer to the point in time the data was collected. The results from the equal variance test display a p-value of 0.729, which is greater than the significance level of 0.05. From these results, it can be concluded that the variances between the two samples are not significantly different. The results from the equal variance test are shown in figure 15:

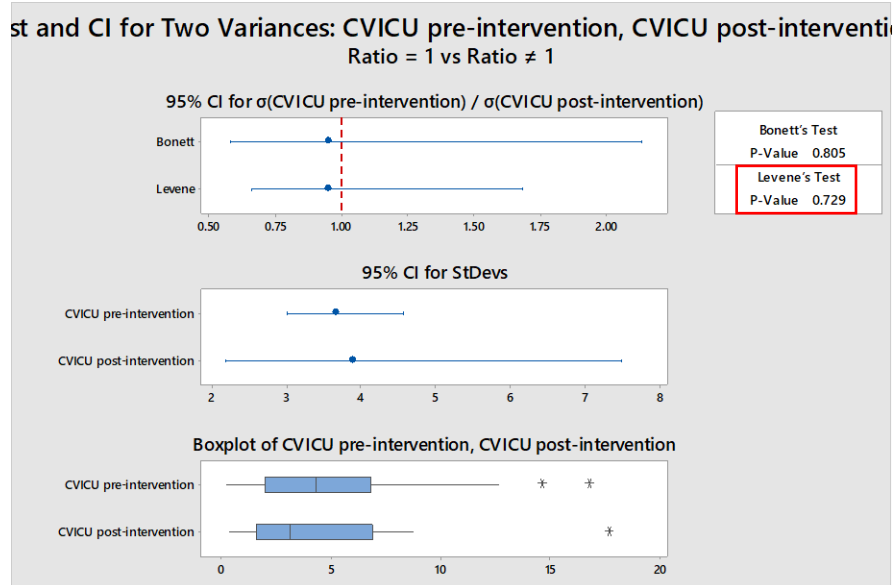


Figure 15: Equal variance test for the two data sets collected from CVICU.

After the equal variance assumption was evaluated, a two sample t-test was run to determine if the mean had changed significantly over time. The p-value from the two sample t-test, 0.507, was greater than our significance level of 0.05 so the means do not differ significantly. The results from the two sample t-test for CVICU are shown in figure 16:

Two-Sample T-Test and CI: CVICU pre-intervention, CVICU post-intervention

Two-sample T for CVICU pre-intervention vs CVICU post-intervention

	N	Mean	StDev	SE Mean
CVICU pre-intervention	72	5.05	3.65	0.43
CVICU post-intervention	23	4.46	3.87	0.81

Difference = μ (CVICU pre-intervention) - μ (CVICU post-intervention)
 Estimate for difference: 0.592
 95% CI for difference: (-1.171, 2.354)
 T-Test of difference = 0 (vs \neq): T-Value = 0.67 P-Value = 0.507 DF = 93
 Both use Pooled StDev = 3.7053

Figure 16: Results of the two sample t-test for CVICU.

DISCUSSION & CONCLUSION

Conclusion of Results

From the results of the two sample t-test run on CVICU, it can be concluded that mean alarms per hour per bed did not significantly change independently as time elapsed. The p-value from the test displayed that at the 95% confidence level, there was not a significant change in mean from the beginning of the study to the end of the study. From the results of the two sample t-test run on 4RC, it can be concluded that there was no significant change in mean alarms per hour per bed from pre intervention to post intervention. It can be concluded that the educational program and hands on training did not lead to a significant decrease in mean alarms per hour per bed. The results suggest that the intervention presented to the staff was not a sufficient tool to help alleviate the clinical alarms management problem.

Outside of Scope Discussion

Two very interesting points have been brought up but are outside the scope of this particular study; however, they should be analyzed to help minimize the clinical alarms management problem. The two points are:

1. Nurses keep alarms on for patient safety; however, when they do not monitor those alarms adequately, patient safety is compromised by the very device put there to protect them.
2. The hierarchical authority structures between a doctor and an RN or RT stands as a psychological barrier for RNs and RTs when change an order in the electronic health records.

When asked during the follow up meeting why nurses monitor their patients' alarm, they all responded that it was for patient safety: monitoring vitals through clinical alarms helps the nurses keep track of their patients' condition. RNs feel that the alarms alert them to serious conditions that they can attend to. However, the amount of nuisance alarms has made it nearly impossible to detect actionable alarms. Because a nurse cannot distinguish the difference simply by hearing the alarm, and the fact they do not even hear all their alarms, means they cannot attend to all alarms properly. The nurses are struggling to see the impact of managing the alarms better and the direct impact it has on patient safety. The mental barrier that simply turning on an alarm is proper patient safety needs to be overcome by the nurses. Through further intervention and education, it needs to be emphasized that proper patient safety is not having alarms on at all times, but instead managing those alarms well. The RNs must understand that to maintain patient safety, they need to have relevant alarms on for each patient as well as think critically about what alarms are needed throughout a patient's stay in the unit.

The second topic that needs further discussion is the RNs' lack of empowerment to adjust the active order in the electronic health records system. Several RNs have expressed that they feel empowered to change the parameters in Philips, but not to adjust the order. This has caused discrepancies between the two sources of measurements and confusion for other staff. Nurses feel that if they change the order in the electronic health record system, the next nurse to take over that patient once the shift has ended will think that the parameters in the order are the default settings. If the nurse thinks those are the default settings, they may change the parameters again by 10% without an order. Although default settings were printed and placed next to the monitors to avoid this exact scenario, nurses are still hesitant to change the orders. They feel that it is the physician's, and only the physician's responsibility to adjust orders as they see fit.

Limitations

There were several factors that could have had an influence on the results of the study, and these will be discussed before conclusions are drawn from the entirety of the study.

The first point of discussion is the sharing of the intervention with the control group's staff.

When the educational power point was shared with the staff on the intermediate cardiology unit, a few nurses sent the power point on to nurses working in the cardiovascular intensive care unit. The fact that some of the nurses in the control unit were educated using the same power point as the intervention group could have skewed the results obtained from this study. Although no nurses in the CVICU received hands on training, it is still worth noting that some of the staff may have received the educational materials.

Another factor that affected alarm management outside the control of the study, is the presence of the central monitoring unit (CMU). The CMU is a station located inside of the hospital (not in either of the two cardiology units) that helps monitors clinical alarms measured throughout inpatient units in UIHC. The technicians that work inside of the CMU help alert nurses regarding their patients' alarms, and in some cases, can silence alarms for the nurses working on the floor. Although these technicians can silence alarms, they are not allowed to change alarm parameters. Since they are not allowed to change the alarm parameters, their presence does not directly affect the number of red and yellow alarms occurring in a unit. However, they do help with the noise level in the units by silencing alarms for nurses when they are occupied and are not able to do so themselves. At the beginning of the study, during January, the CMU made a shift and were no longer collaborating with 4RC nurses to manage their alarms (CMU does not monitor the ICUs); the nurses heard first-hand the sheer noise their alarms were producing. This inadvertently caused nurses to silence alarms at a higher rate to attempt to deal with the noise created by them.

Since the nurses no longer had help from the CMU, they were struggling to deal with their alarms on an individual basis.

After the results had been collected and analyzed, two final meetings were held with the RNs in 4RC to discuss the educational program. The purpose of the meeting was to provide an opportunity for nurses to express what part of the intervention was helpful, which parts were not helpful, what barriers nurses still faced, and how to proceed further. The staff on 4RC did not express any issues with the educational program, but they were still facing significant barriers.

One of the main barriers they brought to light was the equipment they were dealing with. A new version of Philips was rolled out during March (when the QT and ST alarms were turned on), and with the new version came new equipment. The RNs expressed the difficulties they were having with reading patient names and room numbers on the new Philips home screen, as well as the new bedside monitors that had poor visibility of the pulse oximeter plethysmograph, signal that measures blood oxygen saturation levels placed in the patients' rooms (shown in figure 17 in the appendix). Since the RNs are having trouble seeing this, they do not always remember to address their patient's saturation alarms. Because they are not addressing their patients' saturation alarms as often, more red and yellow alarms have been sounding throughout the unit.

Another issue identified by the staff was that this problem has been evolving in time and complexity, so drastic changes might not take effect. They felt that the intervention had not had adequate time to come to fruition. Taking this into account, a more accurate representation of how effective the educational program was would be to continue to monitor the mean alarms per bed per hour over the next few months.

REFERENCES

1. AAMI. (2011). Clinical Alarms 2011 Summit. Association for the Advancement of Medical Instrumentation (AAMI). Arlington, VA.
2. Cullen, L. "The Iowa Model Revised: Evidence-Based Practice to Promote Excellence in Health Care." Department of Nursing, The University of Iowa Hospitals and Clinics. June 2015.
3. Graham, K. C., and M. Cvach. "Monitor Alarm Fatigue: Standardizing Use of Physiological Monitors and Decreasing Nuisance Alarms." *American Journal of Critical Care*, vol. 19, no. 1, 2010, pp. 28–34.
4. Kauflin, Jeff. "America's Best Employers 2017." *Forbes*, Forbes Magazine, 9 May 2017
5. Korniewicz, Clark, David. "A National Online Survey on the Effectiveness of Clinical Alarms." *American Journal of Critical Care*, vol. 17, no. 1, Jan. 2008.
6. Philips 5-Lead ECG Electrode Placement. PN: LTM8000E-4002A
7. Sendelbach, Sue, and Stavy Jepsen. "Practice Alert: Alarm Management ." *American Journal of Critical Care*.
8. Sendelbach, Wahl, Anthony. "Stop the Noise: A Quality Improvement Project to Decrease Electrocardiographic Nuisance Alarms." *Critical Care Nurse*, vol. 35, no. 4, 2015.
9. The Joint Commission (2011). "Sound the Alarm: Managing Physiologic Monitoring Systems," *Joint Commission Perspectives on Patient Safety*, 6-8, 11
10. The Joint Commission (2013). National Patient Safety Goal (NPSG): NSPG.06.01.01- Improve the safety of clinical alarm systems.

11. University of Iowa Hospital and Clinics (2017). "Clinical Alarms Management Protocol,"
University of Iowa Hospital and Clinics- Inpatient units
12. University of Iowa Hospital and Clinics (2014). Clinical Alarms Management- Adult,
Inpatient: PC-PCI-05.38- Establish institutional guidelines that ensure the effectiveness
of clinical alarms for patient safety

APENDIX

Table 1: Default parameters for relevant physiological clinical alarms.

Physiological: +10%	
Parameter Name	Default Setting
ECG: High Limit	150bpm
ECG: Low Limit	50 bpm
BP: Sys. High	160 mmHg
BP: Sys. Low	90 mmHg
SpO2: High Limit	1
SpO2: Low Limit	0.85
SpO2: Desat Limit	0.85
QTC High Alarm	500 msec

Table 2: Default parameters for relevant arrhythmia clinical alarms.

Arrhythmia: On/Off	
Parameter Name	Default Setting
Non - Sustain VT	On
Run PVCs	Off
Pair PVCs	Off
R-On-T PVC	Off
Vent Bigeminy	Off
Vent Trigeminy	Off
PVC Rate	On Adult: >10 PVCs/ min
Multiform PVC	Off
Pacer Not Capture	On
Pacer Not Pace	On
Pause >	On
Missed Beat	Off
SVT	Off
AFIB	Off
SVT Run >	On 10 SVs
Irregular HR	On
ST Analysis	On
QT Analysis	On

Q9 - How many of your patients' alarms would you consider false alarms?

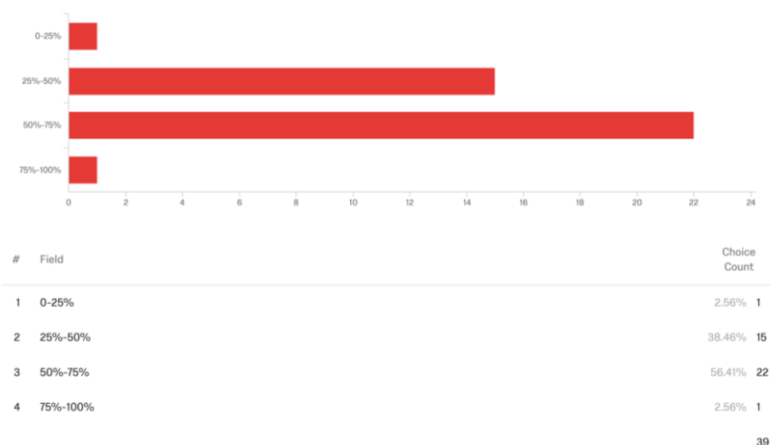


Figure 9: Results from survey regarding how many false alarms RNs estimated their patients' were experiencing.

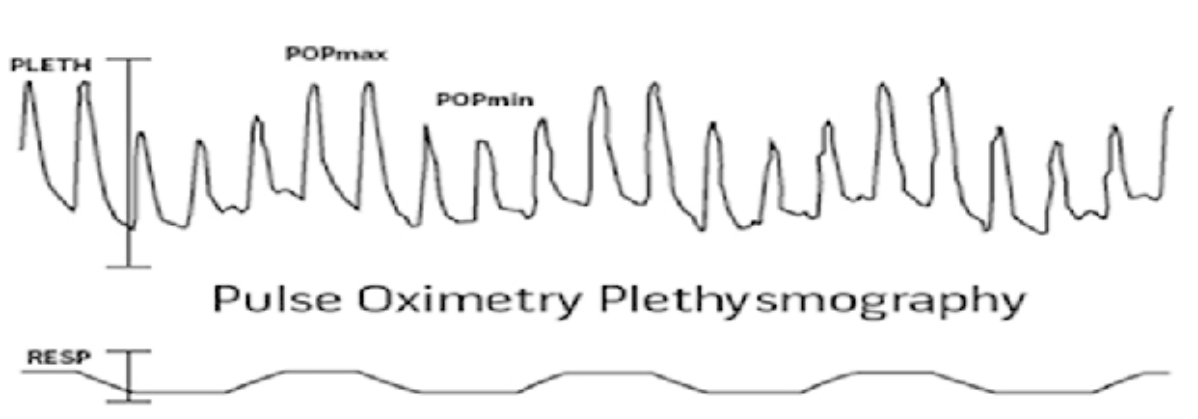


Figure 17: Pulse Oximetry Plethysmography that displays on the bed side monitors for blood oxygen saturation levels.